Controlled Thermo-Mechanical Processing

Innovative hot deformation technology tailors microstructure to tube and pipe manufacturing

Manufacturing steel tubes and pipes involves reheating steel billets to forging temperatures, followed by a series of piercing, elongating, and reducing operations to obtain the required dimensions. The product often receives post-processing heat treatment to improve the steel microstructure – the shape and distribution of grains – that dictates the product's hardness and other physical attributes. With recently developed deformation models and the advent of faster computers, the potential exists to develop control technologies to produce the desired microstructure right off the mill, eliminating the need for the costly post-processing heat treatments. The application of controlled thermo-mechanical processing (CTMP) will enable consistent products to be made with targeted structure and properties while minimizing time and energy inputs.

The Timken Company began a collaborative effort to design and control hot deformation processes for making seamless mechanical steel tubing through the application of thermo-mechanical fundamentals. Thermal, mechanical, and metallurgical results of the research were integrated into a tube optimization model (TOM) to help manufacturers define processing recipes that would produce targeted steel microstructures. It has been demonstrated for the spheroidized annealing cycle for through-hardened steel and for a new heating recipe for automotive gear steels. By quantifying the effects of various combinations of annealing times and temperatures on carbide particle size, shape, and distribution, TOM has improved steel surface quality while shortening annealing times, increasing manufacturing productivity, and reducing natural gas consumption.

Seamless Mechanical Tubing Cooling After Production

Benefits for Our Industries and Our Nation

- Eliminates post-processing heat treatments
- Decreases natural gas consumption
- Reduces the need for remanufacturing product
- Reduces product variability and improves product surface quality

Applications in Our Nation's Industry

The CTMP technology has the potential for widespread application in all major sectors of the domestic tube and pipe industry; two of the largest sectors are seamless mechanical tubing and seamless oil country tubular goods. It has been proven for the spheroidized annealing heat cycle for through-hardened steels and has led to the development of a recipe for automotive gear steels. Potential applications also exist in the smaller sectors of seamless line pipe, pressure tubing, and stainless tubing. The technology could also apply to non-ferrous metal industries, such as titanium.

Project Participants:

The Timken Company
U.S. Department of Energy's Industrial Technologies Program
Oak Ridge National Laboratory
Idaho National Laboratory
Sandia National Laboratories
Colorado School of Mines
Friedrich Kocks Gmbh & Co.
NACHI Machining Technology Company
University of British Columbia
National Research Council Canada
Scientific Forming Technologies Corporation
Synaps, Inc. (now Engineous Software)

PROJECT PLANS AND PROGRESS:

- The project team developed fundamental models of heat transfer and mechanical deformation for each step in the tube-making process and studied metallurgical characteristics for several grades of steel and processes.
- The thermal, mechanical, and metallurgical results were integrated into a tube optimization model (TOM) to help manufacturers define processing recipes aimed at producing targeted steel microstructures. TOM users can select processing components from an inventory (a virtual pilot plant) and characteristics from three basic steel grades to produce a particular microstructure. TOM also includes a user interface with data input capabilities that enables users to introduce new data from literature or empirical studies. These features ensure that the model remains up-to-date by incorporating new process breakthroughs.
- The CTMP tool was further refined by combining TOM with optimization software, allowing the user to evaluate alternative scenarios for development of robust processing recipes. Ultimately, the use of the TOM will enable tube manufacturers to identify the most capable manufacturing protocols for meeting the customer's metallurgical structure and property specifications while minimizing costs.
- The team also developed an on-line, non-contract sensor to measure the austenite grain size in hot tubes. The sensor relies on ultrasound attenuation and was incorporated into the laser ultrasonic wall gauging technology (LUT), which is another DOE/ITP funded project.

Contact:

Robert V. Kolarik II, Ph.D.
The Timken Company
Phone: (330) 471-2378
Fax: (330) 458-6741
Email: bob.kolarik@timken.com

Steel Program

The Steel Industry of the Future (IOF) subprogram is based in the Industrial Technologies Program (ITP) within the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy. The subprogram works with the steel industry to promote development of more energy-efficient and environmentally sound technology for steel processing. Guided by industry-identified research and development priorities, ITP's steel portfolio addresses those priorities that offer the greatest potential for energy savings in cokeless ironmaking, next-generaton steelmaking, and yield improvement. To learn more about Steel IOF activities, visit the program web site at: www.eere.energy.gov/industry/steel/

A Strong Energy Portfolio for a Strong America

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1-877-EERE-INF (1-877-337-3463)
www.eere.energy.gov

U.S. Department of Energy
Energy Efficiency and Renewable Energy
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